The Northwestern MILLER
MILLING PRODUCTION SECTION

The Influence of Milling Moisture on Flour Yield, Flour Ash and Milling Behavior of Wheat

By E. F. SEEBORG and M. A. BARMORE

EDITOR'S NOTE: This article is a contribution from the Western Wheat Quality Laboratory, Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, USDA., and the Department of Agricultural Chemistry, Washington Agricultural Experiment Station, State College of Washington, Pullman, Wash. Mr. Seeborg is a junior chemist of the staff of the Washington Agricultural Experiment Station and Dr. Barmore is senior chemist of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soil and Agricultural Engineering. The article is an adaptation of the text of an address presented by Mr. Seeborg at the 56th annual technical conference of the Association of Operative Millers, held in Buffalo, May 21-24, 1952. The article is presented in this journal with the permission of the Association of Operative Millers.

DIFFERENCES in bran and endosperm characteristics of wheat are now generally recognized by millers. As part of the program of evaluating the milling quality of new wheat varieties at the Western Wheat Quality Laboratory, Pullman, Wash., it has been found desirable to analyze these differences critically.

Materials and Methods

Elmar, Brevor and Rex, three soft wheat varieties, were selected for the studies. The test weight, ash content and protein content of these wheats are shown in Table 1.

Table 1—Test Weight, Ash and Protein Content of the Three Wheat Varieties Used in This Study

Variety—	Test wt.	Ash* %	Protein* %
Elmar	62.0	1.42	9.1
Brevor	62.5	1.39	8.8
Rex	62.9	1.61	11.0

*14.0% moisture basis.

The Buhler laboratory mill with the micro-milling attachment developed at the Industrial Research Institute, State College of Washington, is shown in Figure 1. This mill was used in milling these samples. Previous work by the authors of this paper and N. H. Shoup with this micro unit attachment had demonstrated that typical milling fractions could be obtained from 100-gram samples and that milling behavior could be predicted from these 100-gram millings.

The three-break sections on the Buhler mill have corrugations of 16, 20 and 24 to the inch, respectively, and the grinding rolls are geared to a 2-to-1 differential with the fast roll running at 565 r.p.m.

The three reduction sections are all on the same set of rolls, roll spacing adjustment being made on the end of each pair of rolls so the second section is always intermediate in spacing to the first and third sections. The speed and differential on the reduction roll is the same as on the break rolls and the surfaces were of a dull finish.

Adjustment of roll pressures was such as to give a maximum reduction of middlings on the first reduction without producing flakes. The middlings of all three varieties are easily reduced and at no time did unreduced middlings appear in the shorts.

In classifying the stocks, 38W scalps were used on the first and second breaks, with a 54W on the third break; and on all of the three reduction streams. For bolting the flour, 12XX silk was used on all break and reduction stocks. These scalp and silk sizes were found to produce results agreeing closely with those obtained on the larger mill.

Subsamples of each of the three varieties used in this test were tempered to five different moisture levels ranging from 9.2% to 16.8%. Break release, bran, shorts and flour yield were determined for all millings on an "as is" moisture basis. The shorts were further fractionated to separate the germ and fine bran, yielding a third fraction which, we believe, represents largely irreducible endosperm residue. It is in this fraction we find the major differences influencing the flour yields and bolting characteristics of the soft white varieties found in the Pacific Northwest. This is the fuzzy "white shorts," or "feed midds," millers in that region are so familiar with.

Results of the Tests

Break Release—The decline in the production of flour middlings as the moisture level of the feed is increased is shown in Figure 2. It will be seen that there is little or no variation in the amount of flour middlings produced by Rex on the moisture ranges from 9% to 15%. After that the curve falls off slightly. Elmar, in the same graph, shows a steady but slight decline as the milling moisture is increased. Brevor shows the greatest decline, with a sharp drop for the 15% and 17% moisture levels. Elmar produced more middlings stock at 17% moisture than did Rex or Brevor at 9%.

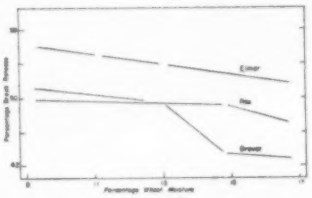

Fig. 2—The influence of milling moisture on break release for three Pacific Northwest soft white wheat varieties.

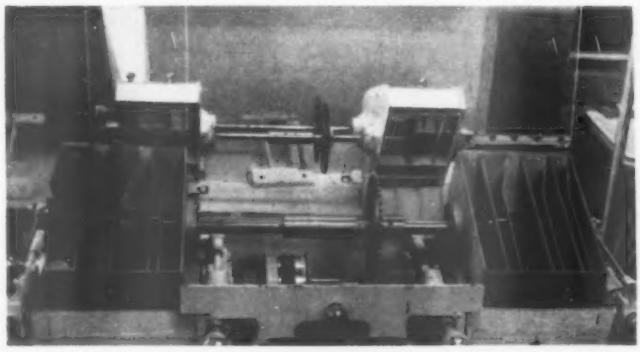

Fig. 1—Detail view of Buhler laboratory mill with the micro-milling attachment developed at the Washington State College Industrial Research Institute.

These wide differences in break releases are due to fundamental varietial characteristics. They are found in wheats, which to all other appearances and grades are the same. These characteristics will be considered more fully later in this paper.

Bran Yield—It is well known that the yield of bran is increased markedly when water is added to dry wheat prior to milling. This is desirable up to a certain point, since it helps separate the bran coat from the endosperm and aids in the production of a well-dressed flour. Differences in the structure of the bran layer exist among varieties, however, which also influence the yield of bran and the effect of increasing moisture content upon it.

Studies of the relative thickness of the bran and aleurone layers of Pacific Northwest wheat varieties have been conducted at the Northern Regional Research Laboratory and those studies by R. A. Larkin, M. M. MacMasters, M. J. Wolf and C. E. Rist indicate that while bran thickness in soft white wheats was not correlated with milling characteristics of the endosperm, there were significant differences, both in the structure of the bran layers, and in thicknesses.

Rex wheat does not have a thick bran coat, but it has a significantly different bran and aleurone layer structure which may partly explain its brittleness and poor cleanup.

The influence of moisture content of bran yield is shown on Figure 3 on each of the three varieties studied.

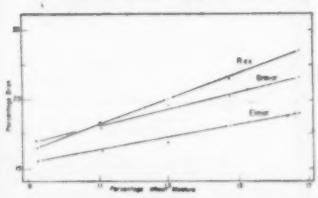

Fig. 3—The influence of milling moisture upon the bran weight for three Pacific Northwest soft white wheat varieties.

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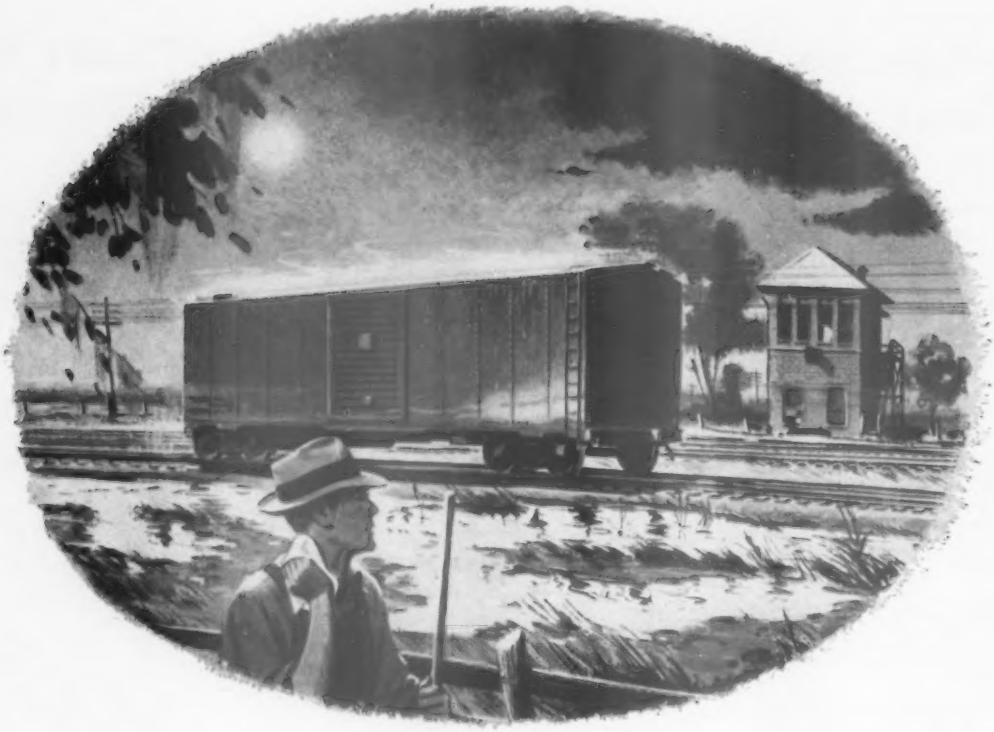

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A Baking Technologist Thinks Aloud

By George Garnatz

Director, Kroger Food Foundation

SUPPLYING our nation with its daily bread is basically important and brings into play a chain of events which emphasizes the interdependence of modern society. Bread is not the result of the efforts of the baker alone, but is the end product of an integrated system beginning with a bounteous Providence which provided the cereal grain, wheat. This grain, endowed with proteins of a unique character make it possible for man to enjoy bread in the light-risen, well symmetried, velvety-textured and nutty-flavored form it is found today.

Next comes the breeder of wheat who sees to it that the varieties available for production are well fitted, again from a number of viewpoints. It must yield well for the farmer. It must be disease resistant and should stand well in the field. Good milling characteristics must be bred into it and finally, it must lend itself to making bread of highest quality under modern methods of mechanized mass production and in the smaller retail shop as well.

Since it requires about 15 years to develop a new variety of wheat, the wheat breeder must carry on his work with foresight. Within that space of time, practices in milling and baking, currently in vogue, could well change and become obsolete. The wheats may be called upon, after having been milled into flour, to perform over a wide range of conditions.

Consequently, in his program, the wheat breeder must be careful not to commit himself too definitely into the future and must refrain from restricting the range in wheat characteristics. It would seem that flexibility and adaptability lie in the direction of a reasonable number of wheat varieties, basically sound agronomically, satisfactorily millable gauged by present methods and with an eye to the future and functionally so versatile that miller and baker have available to them the device of blending in order to tailor a flour to a specific job.

Farmer Not Independent

The farmer-producer constitutes the next link in the system. His is the responsibility for the exercise of such skillful husbandry as will insure quality crops, in adequate amount at a cost consistent with sound, modern practice. He needs to keep in mind, however, that he is not in business by himself. His customer is not the grain elevator operator or the miller, but the ultimate consumer of bread.

Consequently, the cultivation of any variety of wheat simply because it yields well and without regard for its adaptability for making good bread could militate against wheat competing successfully with the other elements in the increasingly varied American dietary for a significant portion of that dietary.

The miller-converter takes up the baton as the wheat comes to him. Through the combined efforts of the grain buyer, the cereal chemist and the operative miller he engages to produce flour compounded of the endosperm material from the wheat, the know-how of the grain buyer, the technical knowledge of the chemist, and the skill of the operative miller.

In listing these three basic elements in the miller's operation, I did not list them in any order of importance. This can't be done, for again, we are faced with the integration of three lines of specialization to a common end. I did place the cereal chemist in the middle deliberately, because I am convinced his services can be used most advantageously as guides in the procurement of a good supply of raw material and in providing information by means of which the operative miller can supervise and control his operation. In his own right the cereal chemist applies his specialized knowledge for building into the finished flour the required properties of absorption, mixing requirement, maturity, alpha amylase activity and basic performance. Since he is in a logical position to do so, his should be the responsibility for quality control.

Baker's Responsibility Great

The baker finally steps into the picture. He performs the second stage of conversion whereby flour is transformed into well piled, golden crusted, even textured, tasty bread, full of ready energy and supplemented in nutritiousness by combining with flour significant proportions of fat-free milk solids, fat, sugar and the elements of enrichment, thiamine, niacin, riboflavin and iron. His responsibility is considerable for in great measure the degree of success he experiences in making his product determines to what extent bread is consumed and to what extent the four-way partnership of breeder, farmer, miller and baker prospers.

It is fitting, and at the same time, indicative of the operative miller's alertness to leave no stone unturned in fitting himself to perform his function intelligently, that opportunity be given upon this occasion to review the needs and practices of the baker; at least insofar as they apply to the operators of large volume, highly geared, mechanized shops. They represent an important sector of the baking industry and deal primarily in the production of white pan bread.

This commodity, which accounts for approximately 85% of the bread made, is produced almost universally by the sponge and dough process in the large wholesale bakeries. This is probably the case because this process appears to embody a considerable degree of tolerance and lends itself well to high-speed, mechanized production practices.

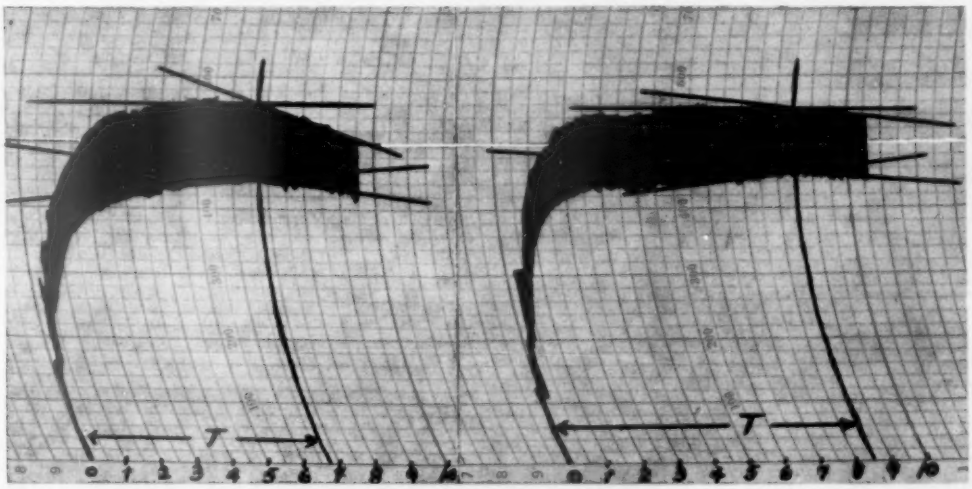

Figure 1—Farinogram, with tangential lines drawn in, to demonstrate method employed to determine Farinograph development time.

Sponge Dough Method Needs Study

Curiously, the sponge and dough process has not been subjected to much organized, scientific study so that much comment advanced on this subject must be scrutinized to determine whether it be based on opinion or fact.

One hears much discussion over the relative merits of cool versus warm sponges. Mention per cent sponge or sponge time and an argument will ensue. No one fully understands just what takes place in the sponge stage of making bread. Evidently something basically effective does. Nevertheless, insofar as I have been able to observe through such studies in which I have collaborated, variables of practice applied to the sponge are not sensitively reflected in the finished loaf. Whether to set the sponge at 76° F. or 80° F. can be left largely to the baker's option. The important thing seems to be that whatever temperature he adopt be attained conscientiously and consistently.

Likewise, per cent sponge is a matter for selection having in mind trough capacity and other factors related to production efficiency. Its proper adjustment is not a critical factor except again, having made one's choice, it should be practiced consistently. Neither is sponge time a critical factor so long as it exceeds three hours. The use of a soft or a stiff sponge, in my opinion, is a matter of arbitrary choice. Even the amount of yeast to be used has settled down to a rather general practice of 2% with only nominal deviations above or below this level.

It may be concluded then, that the sponge is a stage in the bread making process, which, while it triggers what transpires later on, in itself does not require close adjustment but must be handled meticulously and consistently in the interest of attaining uniform results.

Dough Stage Is Critical

In the dough stage, however, things begin to happen which call for closer adjustment and control. The precise adjustment of absorption is important. It provides the foundation for

Underground Grain Storage

By J. A. SHELLENBERGER and F. C. FENTON

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UNDERGROUND grain storage was prevalent in ancient times in the arid climates of the Middle East and Southern Mediterranean regions. More recently the disruption of shipping due to World War II resulted in large quantities of grain accumulating in Argentina where shortages of reenforcing steel for concrete prevented expansion of the conventional type storage facilities, and this led to the construction and operation of underground silos. This was the first large scale attempt to utilize underground storage in regions of plentiful rainfall and where the ground water level is relatively high.

(Continued on page 19a)

dough consistency and, within limits, influences bread yield. Mixing time for development of the physical character of the dough is most important. It determines how well it will yield to the action of the make-up machinery. It incorporates in the dough potentialities for volume, symmetry and close, even texture in the finished loaf. Of course it is essential that all ingredients be charged into the mixer in the correct proportions. Except for malt and yeast food, the proportions can for all practical purposes be arbitrarily selected. As a matter of fact, practice with regard to the amounts of fat, sugar and milk used is considerably standardized, and at the levels currently in vogue, constitute a "land of milk and honey" environment for fermentation. Within the limits of normal practice the selection of dough temperature is of minor importance. Not so, however, with floor time which seems to be associated more with the physical nature of the dough rather than with fermentation.

Pliable Doughs the Goal

Up to this point one objective has been to achieve such a measure of pliability or extensibility in the dough that it will handle well and machine well over the make-up equipment. One aspect of economic significance is to have a dough that will divide well in order that the loaf units may be of uniform weight well adjusted, with due allowance for bake-out, cooling and slicing losses, to yield a loaf of prescribed weight without undesirable under-weight and inefficient over-weight. Much of the provision for bread quality built into the dough in the mixer can be lost if adjustment of the molder is not attained and maintained. In the course of sheeting, a good job of degassing must be accomplished without tearing the dough, to be followed by a reasonably tight curl and subsequent compression which gently and progressively, but effectively seals and extends the dough cylinder.

More and more generally mechanical panning devices are being used. They do not however, relieve the baker of the responsibility to see that this operation is done properly for otherwise loaf shape and symmetry may be adversely affected.

In the steam box, where the pan proof takes place, the effective temperature employed is secondary, provided it falls within the range of accepted practice. What is more important is that steam box conditions be uniform as to temperature and humidity. This latter factor must be high enough to prevent crusting of the dough. What is of transcendant importance, and frequently overlooked by bakers, is that the dough must be proofed to just the right height.

Much bread suffers from abuse in the steam box. There it is that the potentialities for good bread built into the dough in the mixer can be wiped out. If the dough be underproofed, then the loaf will burst along the side and texture will be coarse and irregular. When the dough is over-proofed the loaf will lose symmetry and the texture becomes open, round-celled and crumbly. Careful control of the proofed height of the dough must be practiced if bread quality is to be realized.

Transformation in the Oven

Vigilance on the part of the baker cannot be relaxed while the dough is in the oven. Here important changes take place. As the temperature of the dough rises, the starches dextrinize so that the greatly stepped up activity of alpha amylase has something on which to act. At the same time forces of expansion begin to act through the carbon dioxide and moisture vapor present. When the dough temperature rises some more, yeast and enzyme activity are arrested. Then the gluten is "set" through coagulation and ultimately the crust is formed and then is caramelized to an inviting, golden brown color.

Care must be exercised not to form the crust prematurely by which volume is throttled, the side bursts and texture becomes coarse and irregular. Rather the bake should progress cautiously for about the first five to seven minutes to encourage the dough to attain its full volume and symmetry. It is in the oven where the fruits of all previous effort pointed toward peak development of the dough are enjoyed. The objective is to achieve such a measure of extensibility, such an intimate dispersion of air in the dough and such a measure of gas retention that as the temperature of the dough rises in the oven, it will react sensitively to the expansive forces while at the same time permitting them to do their work effectively and yet so progressively that close, even, elongated cell structure results. These qualities are built into the dough in the mixer and are conserved and facilitated by the subsequent processing steps and will be realized in the oven only if diligent control has been maintained.

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view thus sketched will provide a suitable backdrop against which to project the role of flour as the basic ingredient of bread and how its characteristics are evaluated in the laboratory.

Fermentation in Secondary Role

There was a time when the proper adjustment of fermentation was of major importance in the attainment of uniformly good bread quality. Along with advancing knowledge it has assumed a secondary role. We understand more clearly how the action of the enzymes on wheat starch contribute to fermentation tolerance and appreciate as never before that the physical characteristics of the dough are importantly influential in determining bread quality. It is estimated that currently, 70% of the job of making uniformly good bread under commercial conditions is related to the proper adjustment of the physical properties of the dough.

Of Interest to Millers

Of interest to operative millers then, in order that they might collaborate in tailoring flour to the baker's needs, should be some discussion of the factors that enter into the make-up of flour, their significance and how they are evaluated in the laboratory. In what is to follow there is much room for difference of opinion, opportunity for some selectivity within the general framework to be set up and a viewpoint which represents primarily that of the large-volume wholesale baker.

Ash is still used as a basis for trading in flour. Consequently, it cannot be ignored. It will be dealt with, however, in but general terms. Within the mill, it serves a useful purpose as an index to control flour grade, as a check on uniform milling and as a measure of wheat uniformity. If it correlates with baking performance, it does so only in a very general way. In its application outside the individual mill, it is alleged, the emphasis placed upon it is not warranted. The test does operate under limitations. It is accused of contributing to false values, economic penalties in the mill and the rejection of good milling and baking wheat simply because the ash content of the wheat is high.

It is to be hoped that in time some other test for flour grade will be devised that will define flour grade with greater fidelity and with acceptable accuracy. With this in mind, the colorimetric method proposed by Dr. D. W. Kent-Jones and his associates should be evaluated for its applicability in the American milling picture.

Flour protein content, along with fermentation, has been relegated to a position of secondary importance. Apparently, protein quality is a factor as well as the amount of protein. To the baker therefore, protein quantity is a factor worthy of note merely as an index of flour uniformity. The level he specifies is selected by him, having in mind baking performance for the baking schedule he maintains, the type of loaf he desires to produce, and in relation to absorption, bread yield, protein premiums and the level of protein a particular crop provides.

Standardization of Enzymic Activity

The supplementation and standardization of the enzymic activity of flour has contributed significantly to better and more uniformly performing flours. We can remember the difficulties encountered with what later was identified as diastatic deficiency. When enzymic supplementation was first introduced it was recognized that proper treatment provided baking tolerance and adequate sponge fermentation. Later came an appreciation of the fact that beneficial physical dough conditioning resulted from diastatic activity and later still that alpha amylase activity contributed to the dough's response in the early stages of baking. With the introduction of the fungal amylases (available for use by the baker, but not by the miller) our idea of "malting" is boiling down to the action of alpha amylase on the wheat starch and the resultant effect on extensibility and pliability of the dough for top bread quality.

The measurement of "malting" provides another means for gauging the uniformity of flour. No one factor involved in evaluating flour, by itself, is adequate to obtain uniform response of the flour in the shop. The more factors that can be measured and controlled, the better chance there is of producing or procuring a uniform flour that will yield a uniformly good finished product.

The test for gassing power is more generally used for measuring this factor. It correlates well with baking response. The maltose test is also used. It is convenient for mill control purposes but some prejudice exists against its general use because it does not correlate too well with baking response.

More recently the Amylograph has come into use as a measure of alpha amylase activity. It is felt that by this means some index of alpha amylase activity in the early stages of baking is obtained. The existence of three methods of measurement contributes to confusion so that it is being urged that one test be adopted in the interest of better understanding on this important flour factor.

The fungal amylases are the new-

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est development in this area. They function in the same general way so far as physically modifying the dough is concerned. It is felt their action in the early stages of baking is somewhat more prolonged because they are inactivated at a somewhat higher temperature. They cannot be measured by any of the three methods used for alpha amylase from wheat or barley so that a new method will have to be developed to measure fungal amylase activity.

Maturing (bleaching) or oxidizing is accomplished partly in the mill (essentially with chlorine dioxide) and partly in the bakery with the bromate or iodate in the yeast food. Just what takes place is not too well understood despite all the research study which has been expended on it so that virtually no one attempts to define it in measurable terms. Most generally the baking test is used as a guide in adjusting it.

Some attempts are being made to gauge it by means of the Brabender Extensograph or the Chopin Extensimeter since oxidation is in part at least associated with the physical modification of the dough. The Extensograph involves the formation of a simple, unleavened dough under standardized conditions, which is subsequently rounded, sheeted and molded. After a period of relaxation under standardized conditions of temperature and in effect humidity, it is held at the ends by clamps while a hook much like a candy puller extends the dough to the point of failure. The degree of extension and the resistance to extension offered by the dough are continuously recorded by an appropriate device which yields curves capable of being interpreted in terms of extensibility and buckiness. The Chopin device accomplishes substantially the same thing, utilizes a simple, unleavened dough containing salt, but measures the extensibility of the dough by forming a bubble with it after it has been formed, rested and sheeted to a prescribed thickness.

These mechanical means for specifying the degree of oxidation to be imposed on a flour are not yet widely used for flour specification purposes but they are worthy of mention here because of the implications they may have for the future. At present, for the most part, workers adjust this factor by means of response in a baking test. In many instances its adjustment is delegated to the mill chemist while in others adjustment is achieved by the baking chemist and the mill chemist conferring together.

The physical testing of doughs largely embraces the use of the Brabender Farinograph. I assume you are all familiar with it, which makes its description at this time unnecessary. It is used to measure a flour's absorptive capacity as well as its mixing requirement. Assuming a standard bread formula and a standard bread processing procedure, and assuming further, that the flour has been adequately "malted" and matured, then the attainment of uniformly good bread quality boils down to properly adjusting absorption and mixing in the dough stage.

Consequently, more and more operative millers are being made conscious of these two factors through their contact with mill chemists and they want to know what it is all about, how significant are those factors, can they be measured in different laboratories with a satisfactory degree of agreement and how does the baker apply them.

Significance of Absorption

Let us look at absorption first. Obviously, it is associated with that physical characteristic of dough

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which, for want of a better term, is designated consistency. The proper adjustment of consistency is fundamentally important in contributing to the way in which the dough will machine and handle. Primarily, good machinability is sought in connection with bread quality. It also is desirable in the interests of economy in the use of dusting flour, freedom from doubles and cripples and minimizing stick-ups, the latter two of which detract from efficiency in the make-up unit by reducing the actual rate of production.

Absorption is of interest to the baker for another reason. Within certain limits it is associated with bread yield. The legal maximum moisture content for bread is 38%—one hour or more out of the oven. A low absorption, such as would not permit attaining a bread moisture content close to, but not exceeding 38%, will reduce yield. As absorption is increased, bread yield will increase until finally a level of absorption is reached beyond which bread yield cannot be realized without exceeding the allowable moisture content for bread.

The use of such a level of absorption (or one that is lower than the ideal for maximum bread yield) can only be justified if it be needed to impart the machinable dough consistency required for good bread quality. Otherwise, in the case where absorption, higher than needed for maximum bread yield, is used, the baker merely qualifies for the dubious privilege of incurring higher fuel cost to convert water into steam.

Having briefly outlined the significance of flour absorption, let us turn our attention to how it can be measured, to what extent laboratories can obtain results which agree, what application can be made of such results and some advantages that are enjoyed as by-products of the objective measurement of absorption. The Brabender Farinograph is used quite extensively for this purpose. The large bowl for this machine is recommended because our experience leads us to believe that with it flours are somewhat more sensitively characterized with respect to their mixing characteristics. We prefer to use a flour sample of 300 grams on the "as is" basis because we find the absorption value thus obtained can be more directly converted into terms of shop practice. After the flour sample has been introduced into the mixer and, with it running, water is gradually added from the calibrated burette until a dough consistency is attained such that the amplitude of the Farinogram is centered on the 500 consistency line of the Farinograph chart. The burette is so calibrated that the amount of water used can be read directly as per cent absorption.

Agreement Between Laboratories?

By this means can different laboratories obtain results which agree? To illustrate that they can, two tables are presented. The first one involves the results obtained on 10 consecutive cars of a given type of flour originating from one mill. In parallel, for each car, are listed the Farinograph absorption results obtained by the mill laboratory and the bakery laboratory. Note how consistently, in each individual instance, the two laboratories agree within less than one percentage point and in many instances within closer limits. On the average they agree very closely even though the bakery laboratory's "as is" moisture content of the flour is slightly lower than the moisture content of the flour when the mill laboratory tested it.

Table 1—Agreement Between Mill and Bakery Laboratories in Measurement of Flour Absorption

(Per cent absorption)

Car	Mill laboratory	Bakery laboratory
1	63.3	63.2
2	63.0	62.6
3	63.7	63.9
4	63.1	63.5
5	62.6	63.5
6	63.0	63.4
7	63.2	62.9
8	62.6	63.2
9	62.8	63.5
10	63.0	62.7
Average	63.0	63.2

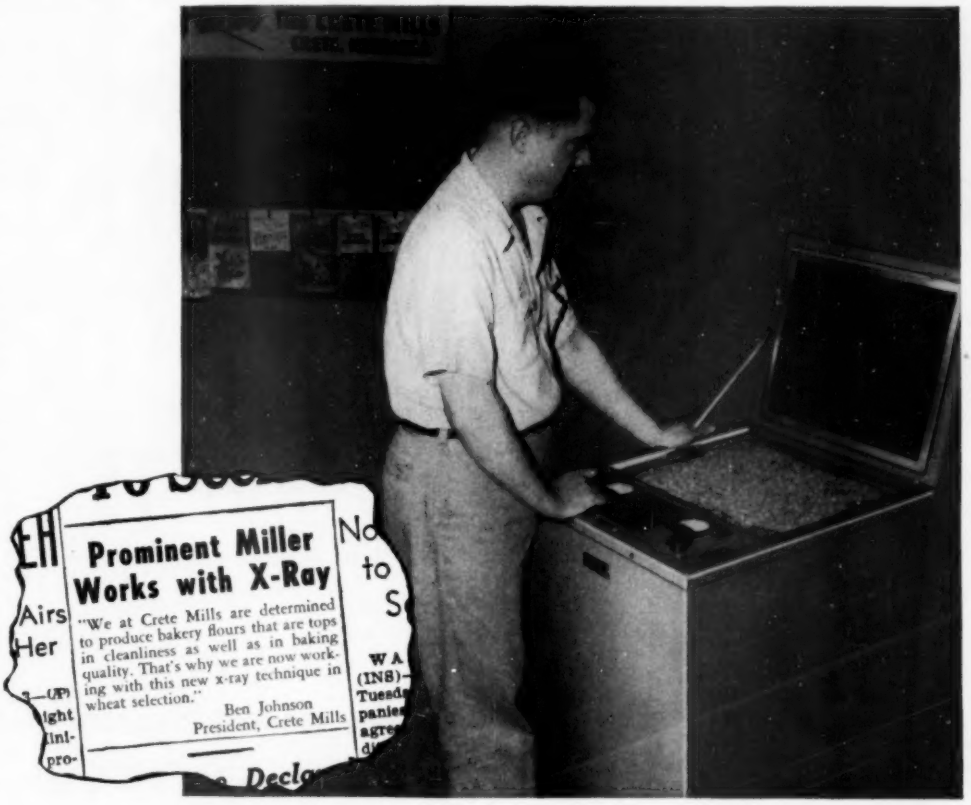
In the second table have been tabulated the average absorption results from seven different mills in comparison with the corresponding results reported by the bakery laboratory. Where available, the averages for two periods of time for a given mill have been included. It should be pointed out that in every instance the bakery laboratory is the same one. The individual averages agree within about one half percentage point, except in one instance, while the over-all average is in quite close agreement.

Now, what application can be made of such results? The results may or may not be capable of direct application to bakeshop practice, depending upon the formula used, the baker's choice of the level of dough consistency with which he desires to work

Table 2—Agreement Between Seven Mill Laboratories and a Bakery Laboratory in Measurement of Flour Absorption

(Per cent absorption)

Mill	Mill lab. result	Bakery lab. result
A	61.0	61.4
B	62.6	62.0
B	62.3	62.5
C	62.0	62.4
C	61.9	62.1
D	61.3	61.1
D	61.4	61.8
E	61.8	62.4
E	61.9	62.2
F	62.8	63.1
F	63.0	63.2
G	61.0	61.8
Average	61.9	62.2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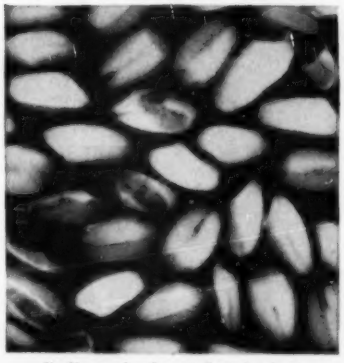


Radiograph of an infested wheat sample, section enlarged three times.

and the peculiar characteristics of the shop. There is reason to believe though, that for all practical purposes, a relationship can be established between Farinograph absorption and shop practice which will permit the bakery laboratory to pass on to the baker an absorption figure for a given car of flour that can be used in the shop with little or no further adjustment. Such guidance contributes significantly to the production of uniformly good bread at a level of absorption consistent with maximum bread yield provided, of course, that the baker has under control other factors that also affect bread yield.

Absorption an Objective Measure

Farinograph absorption results provide an objective measure by which the baker can express his requirements to the miller, who in turn, is in a position to know whether he has or has not met this specification. Psychologically it provides the miller with incentive to study the factors under his control which contribute to maximum absorption. Absorption results, freely exchanged between miller and baker have provided such a measure of collaboration that in several instances millers have been able to improve slightly, but bread yield-wise desirably, the absorptive capacity of their flour.

Having determined the flour's absorption by means of the Farinograph, the mixing bowl is emptied, thoroughly cleaned and reassembled. Another charge of 300 grams of the flour under test is introduced, the mixer is started, the per cent absorption previously determined is added and the simple flour-water dough thus formed is mixed nine minutes or longer. By this process a Farinogram is recorded which is then interpreted in several ways. Some workers make use of valorimeter values, others the M. T. I. factor and still others the time to reach peak or optimum development. Since I am more familiar with the latter, we will follow through on its application.

For this purpose let us look at a couple of typical Farinograms to see how these curves are treated to obtain Farinograph development time. (See Figure 1.) First of all, it will be noted that the one comes up to its peak relatively sharply and then just about as sharply drops off. It has a relatively short Farinograph development time which has been determined as follows. Along the upper edge of the curve, a tangent has been drawn, the slope of which follows the rise of that portion of the curve more immediately approaching the peak. A similar tangent is drawn to the falling-off portion of the curve. The point of intersection of the two tangents is then projected down to the time scale of the chart giving the time required for reaching this point. As a double check the bottom edge of the curve is similarly treated. Usually both sets of tangents intersect on the same time line but when they do not, the average of the two time values, thus obtained, is reported as Farinograph development time.

The second curve has been similarly treated. It illustrates how one proceeds with an instance where the peak is not readily apparent since it has been reached very gradually and the break-down is not so sharp. This second curve represents a flour with a relatively longer mixing requirement than the first one.

It has been found that when different laboratories proceed in the same way to determine this factor, substantially good agreement results. In Table 3 are some data, quite current, reflecting the degree of agreement existing between two laboratories based on results from ten cars of the same type of flour. In six out of the 10 instances the two laboratories agree exactly. In only one case are they as much as one minute apart while in three they vary by one half minute. On the average they vary by 18 seconds and the bakery laboratory happens to run toward a higher result consistently where differences exist.

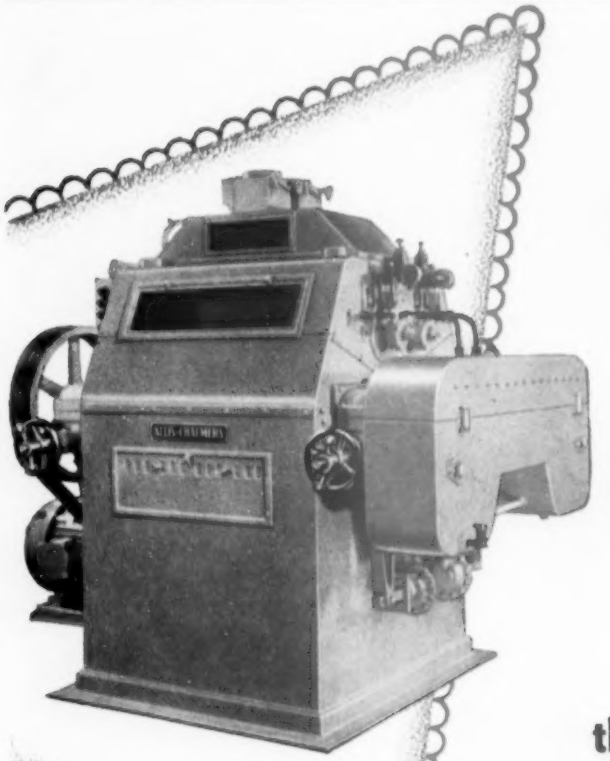
Table 3—Agreement Obtained by Mill and Bakery Laboratories in Measurement of Mixing Time

(Mixing time in minutes)

Car	Mill laboratory	Bakery laboratory
1	6	6
2	5.5	6
3	6	6
4	6	6
5	5.5	6
6	6	6
7	6	7
8	6.5	7
9	6	6
10	6.5	6.5
Average	6.0	6.3

Table 4 compares results obtained by seven mill laboratories with the same bakery laboratory and, wherever possible, two values for a given mill have been included. These are average values for a number of cars, checked over a four-week period from each mill, on the same general type of flour, which incidentally, was milled from hard winter wheat. Except for one case these average results agree within one half minute. The over-all averages differ by only 18 seconds. This is encouraging agreement.

Mechanical modification of the dough to a consistency and a degree of extensibility enabling the attainment of uniformly good bread is being stressed in many quarters. As was said earlier, it has come to be regarded as the major portion of the



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job of making good bread. The opinion is held generally, that mixing requirement as measured by the Farinograph is a significant index. For the baker, it permits specifying objectively to the miller the limits within which flour will fit into his operation.

By measuring the mixing requirement of each lot of flour on the Farinograph before using and, having established a relationship between results thus obtained on many lots of flour and the correspondingly best dough mixing time found in the shop for such lots of flour, he can supply guidance which will permit the application of the required mixing time in the shop more readily and with improved results.

Already applications of this kind have resulted in the rejection of flour with a long mixing requirement even though the baking potentialities of the flour were admittedly satisfactory. Such instances should call to mind that bakers, in the interest of achieving efficient costs of production, need to maintain fairly intensive rates of production and cannot afford to carry unlimited mixing capacity. Moreover, they recognize that unnecessarily rugged flours, requiring prolonged mixing, entail greater power consumption. Consequently, flours which do not fit into such a pattern cannot be used, for if they were, the resultant bread would be on the underdeveloped side.

Mixing requirement is essentially a wheat varietal characteristic. Hence, from the miller's viewpoint, faced with the baker's specifications, Farinograph development time provides the miller with an objective means for establishing his wheat blend so that it will produce a flour in line with the baker's requirements. At the same time it will assure him in advance of delivery that the flour posesses the prescribed mixing requirement.

It should be emphasized that in this review the evaluation of flour has been covered primarily with respect to white pan bread produced in large volume, mechanized shops. Even so there is room for difference of opinion on details since different bakery operators have different philosophies of operation. The problems of the smaller operator, the retail baker, and the baker of hearth-type breads are also different. Nevertheless, it is hoped that in addition to reviewing the practices applied to testing bread flour for this large sector of the baking industry, an approach to the evaluation of bread flours generally may have been sketched which, with modifications, can be applied in the more specialized areas or in accord with individualistic ideas.

At least it is hoped that out of this presentation you may have gained such insight of the advancing technology applied to baking that you, as operative millers, will be better able to team up with the mill chemist to produce flour well attuned to the baker's needs. It is in this manner that you will be able to discharge your share of responsibility in that four-way partnership, wherein the agronomist, the farmer, the miller and the baker combine their efforts and their skills to make baked products that are so good the consumer will be encouraged to use more and more.

Table 4—Agreement Between Seven Mill Laboratories and a Bakery Laboratory in Measurement of Mixing Time

(Mixing time in minutes)

Mill	Mill laboratory	Bakery laboratory
A	5.75	6.0
B	6.25	6.0
C	6.1	5.8
C'	8.0	8.4
C''	8.6	7.6
D	5.3	6.0
D'	5.5	6.5
E	5.8	6.0
E'	5.5	6.0
F	6.1	6.5
F'	6.0	6.3
G	5.6	6.0
Average	5.9	6.2

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Underground Grain Storage

(Continued from page 3a)

The results obtained proved that grain stored in underground bins at a safe moisture content could be held without serious deterioration when the wall construction was impervious to the exchange of moisture from the ground.

With this information to guide them, the Food Supply Division of the Institute of Inter-American Affairs, in its cooperative efforts to assist underdeveloped countries, helped recently the grain preservation situation in Paraguay by adopting underground storage systems based somewhat on the Argentine experience but designed to suit Paraguayan conditions.

The results of this project were contained in the Annual Report to the Bank of Paraguay by Luis A. Gattoni (4). Most of the underground silos constructed in Paraguay were 160-ton (5,878 bu.) capacity. The excavations were made principally by the use of bulldozers (see Figure 1) which reduced the amount of labor required and hastened construction appreciably.

The main construction material for the silos was native brick which was in turn given a cement plaster coating as illustrated in Figure 2, and the cement covered with moisture-impervious paint. The storage pits were covered with tar paper roofs supported by wooden frames. The silos when filled were covered at the surface with water proof paper, cemented with asphalt paint at the edges and borders to provide as nearly as possible a hermetic sealing. In this manner grain was preserved for long periods of time with low investment for storage structures. The Institute of Inter-American Affairs has rendered a valuable service to Paraguay by providing the technical aid required to put this project into operation. The program was financed jointly by the U.S. and Paraguayan governments.

When the underground soils were carefully and correctly constructed, grains at moisture levels below 13% have been stored without deterioration for years. In Paraguay grain, principally corn, usually has been dried artificially and fumigated before being placed in silos. Evidence in-

ABOUT THE AUTHORS — Dr. Shellenberger, head of the department of milling industry, Kansas State College, Manhattan, is a frequent contributor to this journal. Mr. Fenton is head of the department of agricultural engineering at the Kansas Agricultural Experiment Station and is an authority on farm grain storage. This article is contribution No. 208 from the department of milling industry and No. 77 from the department of agricultural engineering, Kansas Agricultural Experiment Station.

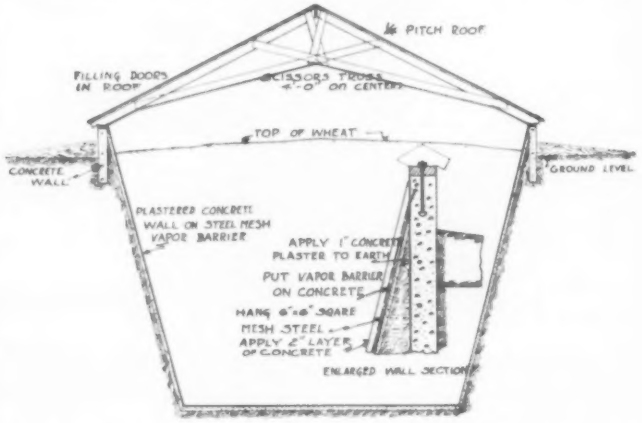
½ PITCH ROOF
FILLING DOORS IN ROOF
SCISSORS TRUSS 4'-0" ON CENTERS
TOP OF WHEAT
GROUND LEVEL
CONCRETE WALL
PLASTERED CONCRETE WALL ON STEEL MESH VAPOR BARRIER
APPLY 1" CONCRETE PLASTER TO EARTH
PUT VAPOR BARRIER ON CONCRETE
HANG 6"x6" SQARE MESH STEEL
APPLY 2" LAYER OF CONCRETE
ENLARGED WALL SECTION

Figure 3. Cross section of a suggested design for an underground storage bin for western Kansas.

Figure 1. Excavation for an underground grain storage silo in Paraguay. The tractor operated bulldozer can dig this trench under contract for as low as 15¢ per cu. yd.

dicates that there has been but slight loss due to insect damage during storage.

Because of the success of the underground grain storage programs elsewhere, it seems desirable to call to the attention of the American farmer and the Production & Marketing Administration the possible use that might be made of this type of storage. With certain modifications, underground storage pits such as have proved satisfactory elsewhere might be used in this country. This is especially true in the areas where present storage facilities are lacking and, during years of high production, sufficient railroad cars for transporting it to terminal elevators cannot be supplied.

Underground storage of wheat was tried at the Fort Hays Branch Experiment Station in Kansas as early as 1929. A 100-bu. bin was built of concrete plastered on the earth in a manner similar to the construction of an ordinary farm water cistern. No moisture-impervious barrier was built into the wall and, since the soil was wet in the location, wheat placed in the bin in July had molded throughout the entire mass by the first of November of the same year.

Again 10 years later at the same station (5) one thousand bushels of good quality wheat were stored in an underground concrete plastered on earth type of bin covered with a reinforced concrete slab roof over which two feet of soil was placed. The grain, except for sampling, was left undisturbed for five years. Mold began to form near the walls during the first year and the damaged area increased in thickness each succeeding year, until at the time the wheat was removed from the bin approximately 15 inches of grain near the walls and bottom had molded. It was estimated that 30% of the total wheat volume had molded. The soil surrounding the bin at the start of the experiment was considered dry from an agronomic standpoint, since the soil moisture was only 14%. This moisture content, although inadequate for plant growth, creates a relative humidity of 100% in the air spaces between the soil particles that will cause moisture penetration through walls to dampen and spoil grain. From these studies it was demonstrated that wheat could be stored safely underground only when an effective moisture barrier was provided between the grain and the ground.

More recent valuable experience in the construction of effective vapor barriers has solved that phase of the problem and the time should be opportune with a large crop coming on for the farmers of the Great Plains area to adopt this type of storage.

It would appear that since the cost of building underground grain storage is definitely less than for that of above ground storage such methods should be utilized more than they

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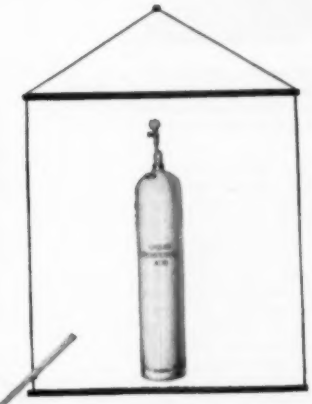

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Figure 2. Portland cement plaster being applied to the interior surface of grain storage silo. These walls must have an effective vapor barrier built into them.

are. The filling and emptying of an underground silo present no difficulties because grain can be dropped into the pit from a dump truck or pushed off the rear of a truck with a minimum of labor and time. Removal of grain from the pit is easily accomplished by modern equipment such as the auger elevator or other types of elevating equipment now in common use in the wheat belt.

That underground grain storage has been successful when the silos have been constructed correctly is a matter of record. This success has been attributed to many causes but probably the main reason grain stores safely in underground silos is due to the more uniform and lower temperature of the stored grain. Soil temperatures are much lower during the hot summer and subject to much less fluctuation than air temperature. For example, subsoil temperatures in Western Kansas are in the neighborhood of 56 to 58° F. This temperature range is favorable for the storage of grain and the uniformity of temperature would reduce to a minimum the "migration of moisture" vapor which has been shown (7) to be one of the principal causes of damage due to "hot spots" and moldiness in stored grain.

The movement of moisture vapor in stored grain can lead to the development of high moisture grain in a particular local area in the storage enclosure, although the grain may have been placed in storage at a safe moisture level. This condition is known to be be due to temperature differences existing within the mass of the grain. Storage structures exposed to the sun's heat in summer and to winter's cold often have a large difference in temperature within the grain mass which will cause moisture migration. Underground storage after the grain was cooled to ground temperature would be much freer from these temperature variations and thus a more favorable storage condition would be provided.

Another advantage that has been claimed for underground silos in Argentina and Paraguay is the slight damage caused by insects during storage. The favorable results reported are attributable to the fact that the grain is hermetically sealed; the reduction in oxygen and accumulation of carbon dioxide caused by the combined respiration of grain, insects, and microflora brings about the asphyxiation of the insects. It is improbable that this is the main cause of the reduced activity of the insects. Experiments where high concentrations of carbon dioxide applied as dry ice have been tried, but the results have not led to satisfactory insect kills. The air interspace between grain kernels occupies approximately 40% of the total storage volume; therefore, under usual conditions sufficient oxygen would be present to last several generations of insects before oxygen would become a limiting factor.

It is probable that the main reason why infestation has not been troublesome in underground silos is the lower temperature at which the grain is held, a temperature at which insect reproduction is very slow. Grain stored in underground bins could be fumigated as effectively, if needed as in any other type of storage structure.

It seems safe to conclude that grain sufficiently dry to place in underground storage would have a moisture content below 13%. When grain of

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this moisture content is cleaned thoroughly to remove practically all live infestation, it would require at least 30 days in underground storage conditions (on the assumption that no carbon-dioxide is lost) to produce a 10% concentration of carbon-dioxide in the silo. Assuming the grain stored to be free from external insect infestation, the infestation that hatched during storage could do noticeable damage before carbon-dioxide would become a hampering influence.

Work of Bailey and Gurjar (1), Lindgren (6), Davidson (2) and Dendy and Elkington (3) have reported on the respiratory ratio of grain and insects under varied temperatures and humidities and on the effect of carbon-dioxide concentration on weevil. More information is needed however, on the temperature of grain during underground storage; the range of temperature changes; moisture migration, if any; and the changes in the oxygen-carbon-dioxide ratio in the air space around the grain during storage. All of these variables should be related to the condition of the stored grain under commercial storage conditions.

The authors believe that if dry wheat in the 12 to 13% range is placed in underground storage and cooled down to ground temperatures as soon as conditions will permit the grain can be stored without loss of quality over long periods of time. The natural conditions of storage are more ideal than in the conventional above ground bins. The much lower cost of construction is also an important item. Underground storage can be constructed for as low as 15¢ per bushel for the first cost and much of this cost is represented by labor which the owner can perform with some additional saving. Above ground storage structures have cost from 50¢ to $1.00 per bushel during the past year.

The following cost estimate (Table 1) of a trench type storage pit similar to the one shown in Fig. 3 is for a capacity of 35,000 bushels, and totals $3,500.00 or 10¢ per bushel. It would be economical storage, even if it cost twice as much. For storages of smaller capacity, the cost per unit will be somewhat higher. The trench type of storage is economical for two reasons: one, the cost of excavation is low when performed with tractor and bulldozer; two, the construction of the wall and vapor barrier can be done with unskilled labor.

The construction of the vapor barrier in the wall is the most critical problem. An aluminum foil laid between two layers of concrete would provide a very effective vapor stop. Asphalt is readily available and cheaper and can be applied without difficulty. The plan illustrated in Figure 3 includes: first, the application of a Portland cement plaster coat of one inch in thickness to the bare soil. After this has set, hot asphalt or rapid curing road oil is applied to the concrete surface followed by a layer of black felt paper. A second heavy coat of asphalt and a second layer of black paper are then applied. Paper should be lapped at the sides and ends and the strips run vertically up and down the walls. A final coat of asphalt is applied over the paper and allowed to dry.

Square mesh 6 in. by 6 in. reinforcing steel is attached to the retaining wall at the top and extended down the wall, across the floor and up the other side, adjoining strips being securely wired together. After the entire interior wall surfaces are covered by steel mesh reinforcing, a two inch layer of rich concrete is plastered on by hand to thoroughly embed the steel in the concrete and make a strong wall. Two applications are required to put on a two inch thick layer.

If gunite operators are available the final layer of concrete might be applied by the air blast method which would give a much higher quality and harder surface than is possible by hand methods. However, quotations received for this work would seem to be too far out of line to be worth consideration.

Conclusions

Experiences in Argentina and Paraguay have proven that grain can be stored safely for extended periods of time in underground structures. The construction must be made to provide a moisture impervious barrier between the earth and the grain. For long storage periods the grain must be dried to a safe moisture level cooled to ground temperatures and fumigated when necessary.

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Table 1—Cost Estimate for 35,000-Bu. Capacity Trench Type Grain Bin

528 cu. ft.—20 cu. yd. @ $12	$ 240	
Concrete for floor and side walls (ave. 2 in. thick)		
2,500 sq. ft. in floor		
5,000 sq. ft. in side walls		
Total—65 cu. yd. concrete @ $12 per yd.	780	
Steel reinforcing		
200 lb. ¾ in. steel bars		
1,750 lb. 6x6 in. square mesh		
2,050 lb. @ 10¢ lb.	205	
Vapor barrier		
7,000 lb. of asphalt @ $50 ton	50	
18 rolls black felt paper @ $3.75	68	
Roof construction		
Rafters—52, 2x8 in. 20 ft. long—1,040 bd. ft. @ 12¢	125	
21 squares of corrugated steel roofing @ $15	315	
Headers—1,000 lineal feet of 2x4 in., 800 bd. ft. @ 12¢	96	
60 pieces—4x6 in. 20 ft. long, 600 bd. ft.	120	
Gable ends, 200 ft. lineal feet 2x4 in., 120 bd. ft. @ 12¢	20	
200 bd. ft. ship lap @ 15¢	30	
Two squares—sheet steel siding @ $15	30	
Total for materials	$2,079	$2,079
Excavation by tractor-operated bulldozer and roll-scraper		
1,665 cu. yd. of earth @ 20¢ yd.	333	
Labor		
Smoothing and completing excavation, 50 man hours	50	
Placing reinforcing steel on walls, 50 man hours	50	
Water proofing, applying asphalt to plastered walls, 72 man hours	72	
Plastering walls over steel mesh, 400 man hours	400	
Carpentry work on roof @ $300	300	
Misc., hardware, grading, etc.	206	
Total power and labor costs	$1,421	$1,421
Total cost		$3,500
First cost per bu. storage capacity		10¢

Wheat Moisture

(Continued from page 1a)

The bran yield of Elmar is significantly lower at 9% moisture and increases less with added water than Rex or Brevor. The brittle character of Rex bran is apparent when it is dry, but is overshadowed by its poor cleanup above the 11% moisture in the wheat. Brevor bran has the poor cleanup characteristics of Rex but is not as brittle.

Elmar bran is tough and releases its adhering endosperm readily, as would be suspected from Figure 3. The differences in bran character shown are entirely varietial in nature. Even larger differences in bran types have been disclosed among hard wheat varieties. One of the experi-

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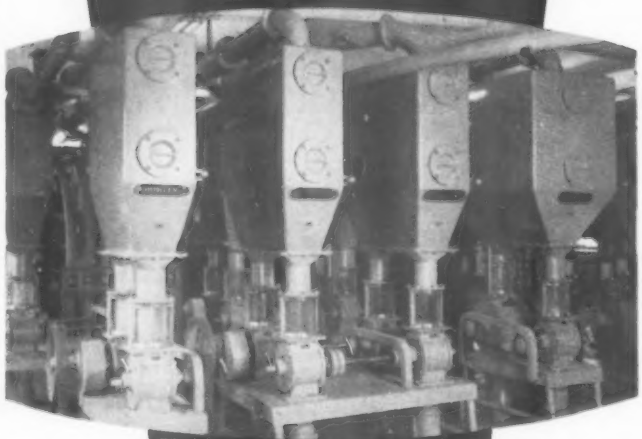

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mental varieties in the Pacific Northwest yields an exceptionally clean, thin and large flaky bran when milled. It is now being used as a parent in the breeding of improved hard wheat in the Pacific Northwest. The successful transfer of this bran characteristic will inrcease the flour yield approximately 3%. Such a potential is more temptation than our Pacific Northwest wheat breeders and agronomists can resist.

Flour Yield and Ash—The influence of added moisture on the flour yield is shown in Figure 4. The bottom line with the steep slope is Rex. Washing or tempering this variety of wheat decreases the flour yield very sharply. The flour yield of Elmar, on the other hand, is only slightly decreased with less than 15% moisture, the yield remaining about the same as between 9% and 13%. Brevor is intermediate with a slope that indicates a low tempering tolerance.

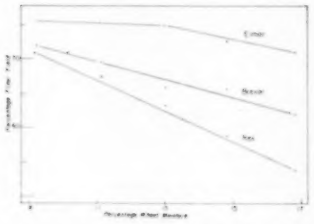

Fig. 4—The influence of milling moisture on flour yield for three Pacific Northwest soft white wheat varieties.

The flour ash content for each of the three wheats milled at each of five moisture levels is shown in Figure 5. While the ash is the same for Elmar and Rex at 9% moisture, Rex is significantly lower at higher moistures. At 17% moisture, Rex has only .28% ash and Elmar .36%. These ash data correlate with flour yield data, but there appears to be a larger difference between flour yields than might be expected from the ash difference.

The yield of Elmar decreases about 1% for each .01% decrease in ash, while Brevor yield decreases nearly 2% for a similar ash decrease. This represents a 100% increase for Brevor compared to Elmar and it is highly significant. This decrease for Rex is 1.3% of the yield for .01 ash—33% greater than that for Elmar.

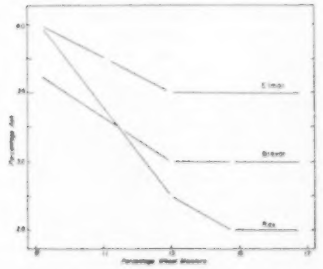

Fig. 5—The influence of milling moisture upon the ash content of flours milled from three Pacific Northwest soft white wheat varieties.

Millers of low ash patent flours have come face to face with this problem many times: How to change the ash a couple of points by simply changing the cut of the mill. Eliminating the tricks of milling, these basic facts remain: (1) Flour from some varieties nearly always yields a lower ash at a given extraction than others. (2) Each variety has its own irreducible minimum, and (3) Each variety has its own slope for the yield-ash-moisture relationships.

Endosperm Shorts. The specific effect on the fuzzy shorts fraction of varying the wheat moisture is shown in Figure 6. Brevor and Rex produce similar results on this figure, which is on a magnified scale in order to better illustrate the differences. Elmar demonstrates a tolerance to tempering moisture because of this fuzzy shorts fraction which we believe is influenced largely by cell wall material, is not increased appreciably even at a milling moisture of approximately 17%. Such wide variations in the bolting characteristics of cell wall material at different moisture levels emphasizes the importance of treating each wheat to its own optimum prior to milling. It has been found in previous studies that tempering mixtures of good and poor milling wheat does not have the desired effect of improving the performance of the poor wheat in the blend.

Discussion

We would now like to discuss a theory which we believe gives at least a partial explanation of why the differences do occur in milling behavior between wheats. Differences in milling behavior of endosperm particles must be due either to structure or composition, or both. Endosperm cells of wheat, like those in seeds of most plants, are storage cells. When cells are formed in the developing channel they, like other plant cells, are composed of cell wall, nucleus, chromosome material, vacuoles and cytoplasm—the fluid of all live cells. This cytoplasm contains minerals, proteins and fats (lipids) but is largely water.

As the wheat kernel develops, protein and starch are deposited in the endosperm. Starch is the chief constituent and continues to be deposited until the plant nears maturity and the moisture content of the cell is greatly reduced. As the water

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leaves the cell a portion of the mineral, proteins and fats migrate but may go only as far as the cell walls which act as filters and allow only the water to go through. Thus, mineral, fats and proteins concentrate in a cell wall region. We believe this may be a partial picture of what takes place during dessication of the maturing wheat kernel.

As a result of recent work at the Northern Regional Research Laboratory under the direction of Dr. MacMasters and reported at the 1952 meeting of the American Association of Cereal Chemists, the picture is more complete. Dr. McMasters and her co-workers found a significant difference in the thickness of the endosperm cell walls as between varieties. They also found, in the same kernel, that cell wall thickness decreases from the outside to the center of the kernel, being thinnest in the "heart" of the kernel and thickest in the region of the crease next to the aleurone layer.

There is now good reason to believe that the ash gradient in wheat endosperm is highly correlated with, if not actually caused by, the difference in endosperm cell wall thickness in different portions of the kernel. This much appears certain. The outer or peripheral area of the endosperm is significantly higher in ash and protein than the center area, as much as two to three times higher, according to studies made by V. H. Morris, T. L. Alexander and E. D. Pasco at the Soft Wheat Research Laboratory at Wooster, Ohio. There is a gradual increase in thickness of endosperm cell walls from the center of the endosperm to the aleurone, the thickest cell walls being 2½ to 3 times the thickness of the thinnest cell wall. This discovery of a relationship between thick cell walls and undesirable milling quality is an important advance in milling research. Cell wall material may cause some varieties to yield a troublesome amount of fuzzy white shorts material due to the thickness or composition, or both, and the amount of this is influenced by tempering. The cell walls of some varieties which are difficult to handle in the reduction system because of this fuzzy characteristic may become toughened during tempering.

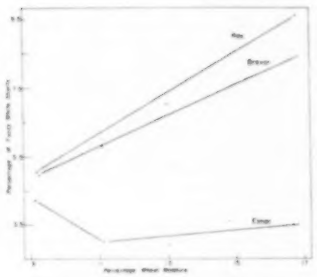

Fig. 6—The influence of milling moisture upon the production of endosperm shorts for three Pacific Northwest soft white wheat varieties.

In this toughened condition they may resist grinding, grade and dress very unsatisfactorily, and are said to have a low tolerance to the amount of tempering water added.

The amount of this fuzzy fraction may depend on, first, the thickness of the endosperm cell walls and, secondly, friability or brittleness of the cell walls. Research is now in progress in the Northern and Western Regional Research Laboratories on the composition of these cell walls.

Circumstantial evidence is not always a valid basis upon which to formulate theories, but it is sometimes desirable to set up a theory, then prove or disprove it by appropriate research which may take years to complete.

Let us continue our theoretical considerations. Good milling wheats like the white wheats, Elgin, Elmar and Hymar found in the Pacific Northwest have thin, brittle endosperm cell walls and a minimum of undesirable component in the cell walls. They also have a high tolerance to tempering and produce granular middlings. The particle size of their flours is medium with a relatively narrow range and with a minimum of extremely fine products.

The minimum ash of those varieties is the highest of the soft wheat types but they have the most favorable yield-ash relationship. How can the above facts be fitted into our theoretical considerations? We believe cell wall and its associated material is high in ash and in protein. It is a cementing material holding not only groups of endosperm cells together as large flour particles, but also groups of starch cells comprising fractured endosperm cells.

As long as the cell wall fragment adheres to the group of starch cells, it will end its journey in the flour bin. This type of endosperm gives free starch cells, which are the portion of the wheat flour lowest in ash and protein, and somewhat less break flour but more break release. Desirable milling qualities associated with this type of endosperm are: high milling capacity, high flour yield, and a good tolerance to tempering water.

A different set of conditions is encountered when a heavier, tougher or more pliable endosperm cell wall contains the starch granules. Varieties with such characteristics would have lower tolerance to tempering moisture possibly because the cell walls get tough and gummy. When they

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break, a lot of free starch cells are released, and less cell wall material adheres to the cell. This type of separation gives more fine granulation break flour of low action protein, less break release, and fuzzy or wooly material in the reduction stock which is composed largely of endosperm cell wall fragments. The influence of added moisture, through tempering water or high atmospheric humidity in milling, has an adverse effect upon the flour yield and the milling capacity.

Those of us in the Pacific Northwest who are concerned with the milling quality of the present and future wheat varieties would like to leave the following thoughts for your consideration:

1. A wide difference in milling behavior of present commercial and experimental wheat varieties does exist.

2. Present methods of detecting desirable and undesirable characteristics require too much grain or are too time-consuming to be applied to large numbers of selections in the plant breeding programs.

3. A long range, nation-wide program is desirable to correlate the efforts of the plant breeder, experimental miller, research scientist and the commercial miller in improving the milling quality of present varieties.

4. A "stock pile" of good milling wheat variety seed in the breeding program is a vital necessity to guard against the constant threat of present varieties by diseases. Varieties used as new sources of resistance are nearly always of unknown quality. Screening of these potential sources of disease resistance for milling and baking quality before they are needed to replace an established variety is desirable.

The staff members of the Western Wheat Quality Laboratory are happy to have had this opportunity to discuss a portion of our work dealing with milling quality of new and presently grown wheat varieties. We consider this technical conference of the Association of Operative Millers to be the best place in the world for these discussions. The excellent cooperation and assistance of the organization's research committee is fully appreciated.

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Mill Dust Losses a Cause for Concern by Plant Management

Examination of the history of dust collecting in flour mills reveals an interesting cycle in the development and application of that type of equipment. The "Perfection" or "Star" type stocking dust collector was the ultimate in collecting equipment from the 1880's until the 1920's.

Several disastrous mill fires of uncontrollable intensity occurred in mills equipped with these collectors and many engineers and insurance companies recommended the use of all-metal collectors. This prejudice against the use of stocking or filter type collectors for inflammable dusts still is held by some insurance companies, but a number of factors are causing mill management serious concern over the apparent dust losses from the average cyclone dust collector.

Due to the increasing concern with industrial dusts by the communities and the increased pressure on mill management for both external and internal sanitation, all dust losses are being studied. In 1948, the Research Committee of the Association of Operative Millers was directed by that organization to investigate the economics of dust control in the flour mill.

The committee's first report, made in May, 1949, called attention to the fact that the dust collectors in the mill collected from five to nine pounds of dust for each 100-lb. sack of flour produced. In that same report, the committee estimated typical dust losses from cyclone dust collectors at an average of 5% of the dust flowing to the collectors. At that time it was estimated that such a loss would amount to more than $3,000 a year for a mill with a capacity of 1,000 sacks daily.

Dust sampling for the purpose of determining collector efficiency is well documented, but the known methods are just now being applied in the milling industry. . . . The discrepancies between previously estimated efficiencies and those determined by a sampling method developed by the AOM research committee has probably arisen because of the very minute amount of dust required to give visible evidence of dust in the clear air discharge of the collector.

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New Developments Broaden Horizons in Wheat Breeding

By L. P. Reitz

THATCHER, Mida, Lee, and Stewart spring wheats and Minter, Quanah, and Ponca winter wheats were regarded as impossible developments until a few plant breeders took up species crosses as a means of effecting the desired improvement in wheat. Species do not or are not supposed to interbreed but these breeders either did not know this fact of taxonomy or chose to disregard it.

Once finding it possible to cross closely related species such as durum and common, emmer and common, and emmer and durum, they branched out to cross wheat and rye, wheat and certain grasses and who knows what they will do next.

For a long time, breeding was done on the basis of two maxims: like begets like, and the contradictory observation that no two individuals are identical. It was further held that continuous selection would tend to fix the desired type. These are essentially true today but the limits of each rule and the basic controls have become understandable only in the last 50 years. The constitution of the offspring following a cross is now rather fully reducible to a scheme or pattern explainable by the laws of cytogenetics.

L. P. Reitz

ABOUT THE AUTHOR—Mr. Reitz is a senior agronomist in the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, U.S. Department of Agriculture. He makes his headquarters at the Nebraska Agricultural Experiment Station and is coordinator of the BPI hard red winter wheat breeding program, including Texas, Oklahoma, Kansas, Nebraska and Colorado, principal region of hard red winter wheat production. Formerly he was on the staff of the Kansas Agricultural Experiment Station and had much to do with the development of the principal varieties of hard red winter wheat now in commercial production in the Southwest.

A Plant Breeder's Flow Sheet

Every plant is the result of the union of units contributed equally by the two parents—pollen from one, egg cells by the other. A wheat plant is both male and female because wheat is self-pollinated. Single-cross hybrid corn results from seeds borne on numerous similar mother plants that were pollinated by equally homogeneous male plants but each with a different inheritance. When the units from the two parents bear the same determiners of inheritance, a true-breeding progeny results. However, when the units are unlike, as in crossing two varieties of wheat, off-spring in later generations may show traits of either parent in various combinations or in new combinations resulting in performance that may exceed the parents. Much of the plant breeding of the present century has been based on this knowledge. Pawnee, Comanche, Wichita, Rushmore, Ceres, and Marquis are a few

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of the varieties of bread wheat developed under the guidance of this method of breeding.

Some characteristics in inheritance have been found to be rather constantly associated in the offspring. This led to the discovery that the thread-like structures, now called chromosomes, observed in the microscopic nucleus of each living cell are the carriers of the very potent determiners of heredity, called genes. It was learned that corn has 20 chromosomes, durum wheats have 28, common bread wheats 42, whereas rye has only 14. It was further seen that these are present in even numbers, actually as pairs, one of the pair being contributed by each of the parents involved. These and other discoveries helped explain a number of previous enigmas of inheritance and plant relationships. Multiples of basic numbers characterized many species; for example, wheats fall into groups with seven pairs (einkorn), 14 pairs (emmer-durum), and 21 pairs (common wheat) of chromosomes, a multiple of seven.

Plant Mules

It was found that crossing a variety with 21 pairs of chromosomes with another having 14 resulted in a plant largely sterile because 14 chromosomes found mates and seven did not. Breeders overcame this partial sterility by selecting for fertility. After extensive breeding work for rust resistance, Hope, H44, Thatcher, Mida, and Lee became available as commercial varieties. The new Ponca winter wheat released in Kansas and Oklahoma gets some of its Hessian fly and leaf rust resistance from Marquillo which, in turn, originated as a durum × common wheat cross in Minnesota.

Lighthouses

All sorts of theories about the origin of wheat and other plants arose out of the discovery of chromosomes in sets of seven in some of the common wheat relatives. It was learned that goatgrass or joint grass, a common grassy weed found in the Southwest, had 14 pairs of chromosomes of which seven were similar to seven in common wheat. The other seven were of different origin. Natural hybrids occur but are entirely sterile. This put E. S. McFadden and E. R. Sears to thinking. Maybe, they reasoned, we could find the wild forms which contributed the three building blocks of seven chromosomes each. So they crossed a goat grass seven with an emmer wheat (14). The result was a plant with 21 chromosomes, totally sterile, except with special treatment. The seed was germinated and the crown packed with cotton soaked with a weak solution of colchicine and grown to maturity. A miracle happened! The plant that once had only one set of goatgrass chromosomes now had two sets; similarly the 14 wheat chromosomes had become doubled and now there were 28. The plant now had 42 (28+14) chromosomes, each had a mate, and seed could be produced by normal methods. This turned out to look like common spelt wheat except for the awns which it bore. This was a clear case of synthesizing a crop out of its wild relatives. Sears and McFadden went on with their work and have now developed 69 new combinations by this procedure.

The possibilities of other kinds of crosses to get plants of economic worth was explored also. Breeders in Russia, Canada, and the U.S. started trying to cross-breed the perennial wheatgrasses with common wheat. Several objectives were in mind including (1) a perennial wheat, (2) a forage plant with larger seeds, (3) greater winterhardiness in winter wheat, (4) disease and insect resistance from the wheatgrasses, and (5) special adaptation features.

Crosses made in 1935 by W. J. Sando of the USDA were the first to be used in this country. Selections from some of his material, developed and crossbred further at the experiment stations in Washington, Montana, California, Oklahoma, Kansas and Nebraska, appear to have very high levels of resistance to several races of stem rust, including 15B, and to certain races of leaf rust. Much more work will be required to get enough of the desired characters combined to make a commercial wheat but new germplasm is here. New germplasm in this case was made available before the need for it became urgent. It is now 17 years since these crosses were started. No one knows for sure whether the resistance can be successfully transferred to bread wheat.

Colchicine, called a wonder drug when first discovered, inhibits one step in plant cell growth and multiplication. Applied when the cells are reproducing themselves, it causes the duplicated set of chromosomes to remain within the cell instead of being separated to form two new cells. This results in a doubling of the chromosome number per cell. Other substances can be used for this purpose also. With some chromosomes to work, will the plants be more efficient or more productive? Many tests have

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been made on this. Certainly when two species are crossed, as rye × wheat for example, to overcome sterility with colchicine is a remarkable accomplishment, for from such a relatively true breeding new species is formed having 56 chromosomes (14 rye + 42 wheat).

Wheat × rye selections were tested over the winter wheat region during the period 1933 to 1937 but were neither as hardy nor as productive as the best common winter wheat varieties. Bread made from these varieties had only fair quality. A. Muntzing of the Swedish Seed Assn., Svalof, has reported results with rye-wheat types somewhat in agreement with ours but on sandy soil certain wheat-rye types yielded about as well as wheat and gave superior bread-making quality and higher protein. He believes that more attention must be given to the utility of these crosses. In the U.S., rye has been resistant to mosaic and may well be explored as a source of resistance to this new killer of wheat.

Luther Smith reviewed the story in barley rather fully in volume 17 of the Botanical Review (1951). He pointed out that doubling the number of chromosomes of barley produces various morphological and physiological changes in the resulting plants. Usually the resulting tetraploids are more resistant to lodging, with greater yield of straw. The leaves and most other parts are larger and the plants a darker green. The heads are more lax and larger but the number of seeds is about the same as or fewer than in ordinary barley. Seeds are larger and have thicker hulls, but do not germinate as well. Malt diastase activity in germinating tetraploid seeds is twice, and catalase activity more than twice that of ordinary seeds. Grain yield per acre has been below that of ordinary barley.

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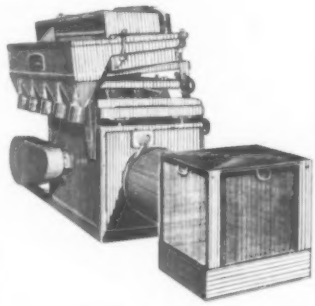

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L. F. Randolph at Cornell University developed several cereals with double the ordinary number of chromosomes and studied these and types developed by other workers. He found doubled rye, barley and sand oats (Avena brevis) were vigorous and relatively fertile. Doubled cultivated or common oats and wheat were invariably dwarfed and deformed in various ways and highly sterile. Writing for the American Naturalist several years ago (1941) he said, "It is wishful thinking to assume that any and all plants can be improved by doubling." Furthermore, he wrote, "While of less immediate value than was predicted earlier, chromosome doubling furnishes the plant breeder with a wealth of new material differing significantly in many respects from varieties at hand."

A dash of cold water at this time administered by Dr. Randolph has had a sobering influence. Breeders realize that the new-found magic would not solve the age-old problems in plant improvement but it opened the gates on several fronts. L. J. Stadler, geneticist of the U.S. Department of Agriculture and the University of Missouri, stated recently that the technic of artificial evolution of species through cumulative hybridization would have been wholly visionary a few years ago and said, "I should hesitate to mention it as a practical possibility even now except for the fact that the better part of the job of developing the procedure has already been done."

Legacies

While the new synthetic species and doubled forms have not come into commercial usage as such, they have become a part of the routine technic for bridging sterility gaps between species. As our search for germplasm is extended, it becomes increasingly important to exploit the superior characters from the wild relatives of our cultivated crops. The line that divides plenty from want, security from uncertainty, or even the ridiculous from the sane, is a fine line at best and certainly a readily altered one. A store of unused germplasm is worth working for so that man's bread supply is kept on the side of safety instead of calamity.

Planning and Administering a Safety Program

EDITOR'S NOTE: The following paragraphs are a summary of a panel discussion at the last National Safety Congress in Chicago. LeRoy J. Collins, safety director, Spencer Kellogg & Sons, Buffalo, was discussion leader. Participants were Roger J. Bear, safety director, The Kroger Co., Cincinnati; Gregg Meyers, safety director, fire prevention and plant protection, Blatz Brewing Co., Milwaukee; J. J. Prabulos, supervising safety engineer, National Distillers Products Corp., New York, and N. E. Theil, director of safety, Southern Dairies, Inc., Washington, D.C.

FOR a safety program to be successful there must be careful and complete planning on the part of the safety department, according to N. E. Thiel.

The safety meetings must be scheduled in advance and the material for the topic to be discussed must be in the hands of the individual responsible for each meeting, well before it is to take place. In this way the men are relieved of the task of preparing their own safety talks. Thus you avoid the common excuses of "No time for a meeting," or, "No topic prepared."

The material for the meeting should be factual material, from the industry involved, and whenever possible from the particular plants involved. This brings home to the men the importance of safety.

The posting of posters, plant and vehicle inspections, along with all other formal parts of the safety program should be planned well in advance. This insures that there will be no unforeseen stoppage of work for a safety meeting, which would upset the supervisor's production plans.

To effectively administer a safety program, you must have the backing of top management, J. J. Prabulos feels. Further, you must maintain a high level of interest all down the line. This can be done by contests, etc., and a thorough job of following up accident reports and hazards found through regular plant inspections.

When the accident frequency goes up on some particular job, or at some particular time of day, the safety man must look to the accident reports to tell him what the trouble is.

When you find that a lot of the men having accidents are new employees, then you must check the indoctrination system, to see if it is functioning properly. If a lot of accidents are happening at night, you must look at the supervisory personnel to see if they are doing their job. An accident report must always contain detailed information as to the conditions under which an accident occurred.

Value of Statistics

Roger J. Bear explained the value of statistics in maintaining an active and interested line organization. They have a need to know where they stand in their department, in their industry, and in industry as a whole.

The primary purpose of statistics, he explained, is in establishing a "par" of accidents for the particular plant or department, at which point you can begin to judge the effectiveness of your program.

In presenting statistics to the line organization, you must make them interesting, by making them real. They must show an improvement, as this gives an incentive to the men.

When statistics are used to compare different industries, or different departments, it is very important that the basis on which they are compared is fair to both parties. The number and severity of hazards which the several departments are subjected to along with the number of man-hours per department must be taken into consideration.

New Program

A brief account was given by Gregg Meyers of the problems he encountered when he set up a safety program in a plant which had never had one. While he had the backing of top management, he at first found little enthusiasm in the line organization.

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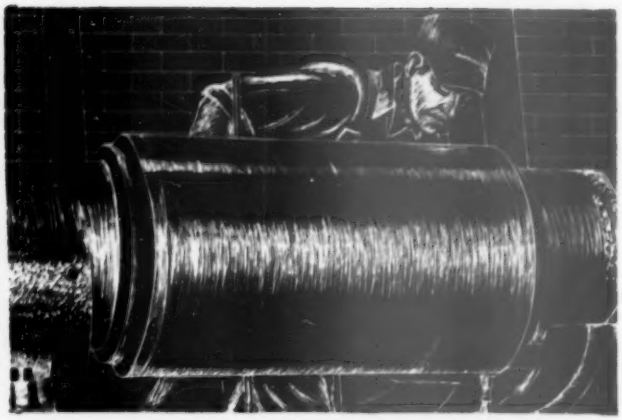

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individual men. In this he found invaluable aid in a cooperative medical department, along with the purchasing, housekeeping, accounting, and other departments. He found it especially effective to take the head nurse out through the plant with him to investigate the scene of an accident. The sight of the starched white uniform seemed to make the men a little more safety conscious.

During the question period which followed the discussion, Mr. Prabulos was asked how to keep safety in the minds of top management. He suggested that through reports and records-of-progress, top management interest could be maintained. Further, they could be induced to take part in various safety ceremonies, such as awarding safety plaques and prizes.

Estimating the Cost

The problem of what basis to use when drawing up a safety progress report was raised. The point was brought out that it was difficult to estimate the cost of severe accidents, especially if they went through the courts, and that while the frequency of accidents tended to go down, the cost of medical and other expenses per individual accident had generally increased tremendously.

Neil A. Madigan, Director of Safety for General Mills' eastern division was asked to outline the safety program they maintained in their Buffalo, N.Y., plants. Among other things, he mentioned that they served violators of safety rules with a "safety summons," which required them to appear before their foreman and explain the causes for the infraction. Anyone in the plant could issue one, through the safety department, and everyone, from top management down, could receive one.

The question was raised as to whether this practice was not taking away a part of the foreman's job. Mr. Madigan felt that it was not, since the man's own foreman would handle any corrective measures involved. The summons is only a warning, and does not carry any penalty, except that the recipient of two summons in any three-month period is exempted from the quarterly "safety dividend" of the company, usually a 10-lb. sack of flour, or something similar.

Preventive Maintenance Applied to Scales

Scales, like all other pieces of mechanical devices, require maintenance. Here again the amount of maintenance depends upon the complexity and the accuracy required.

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Actually, scales are a border line case between an instrument and a production tool. They are used in industry not only to determine monetary values of products, but also as a fast, accurate means of quality control in the mixing and processing of a product.

This latter usage in many cases is of as great importance to the producer as the actual portioning out for sale.

Even though scales do play a vital role, most users, while they may be conscious of maintaining their other equipment, seem to overlook the importance of proper maintenance for their weighing devices. Yet in most cases all that is needed in the way of preventive maintenance is that it be kept clean and free.

Once a scale unit is installed correctly, with rigid supports and so placed that it receives the commodity without excessive abuse, it will operate properly for many months with only frequent dusting and inspection of the dashpot, if one is used.

As for overhauling or replacement of parts on a scale, this work should be done by personnel familiar with weighing devices and who have had instruction in the art.

Companies which use a great many scales have found it advantageous to set up a scale department that has complete charge of the installation and maintenance of all of their weighing equipment. Some companies have found it useful to retain records of each scale, with information as to purchase date, specifications, the date of the last overhaul and the parts that were replaced.

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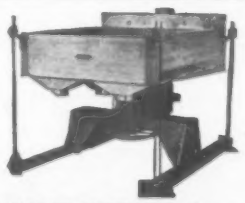

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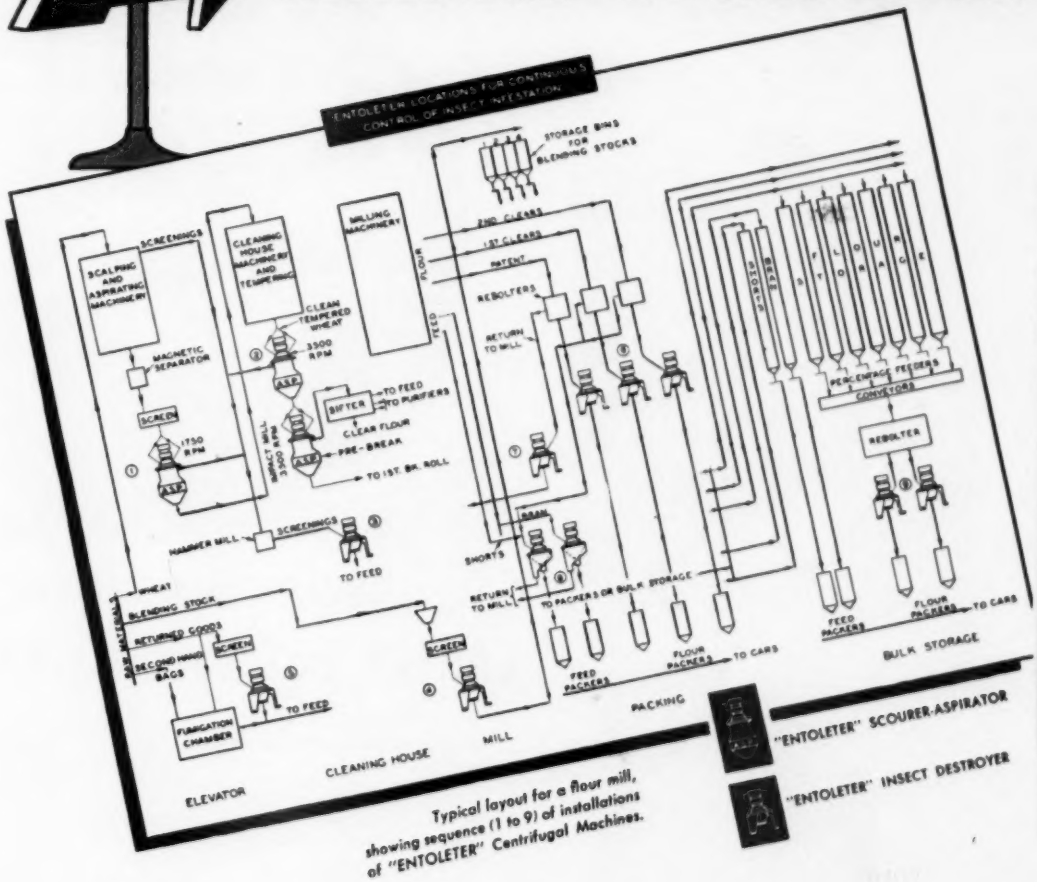

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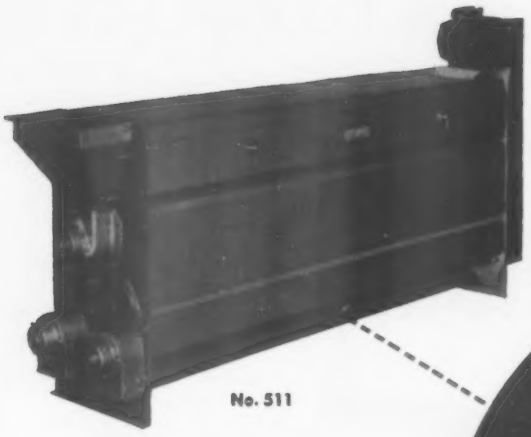

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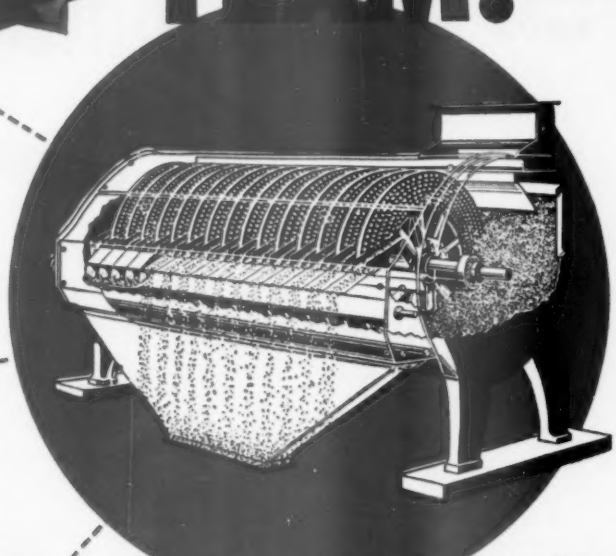

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